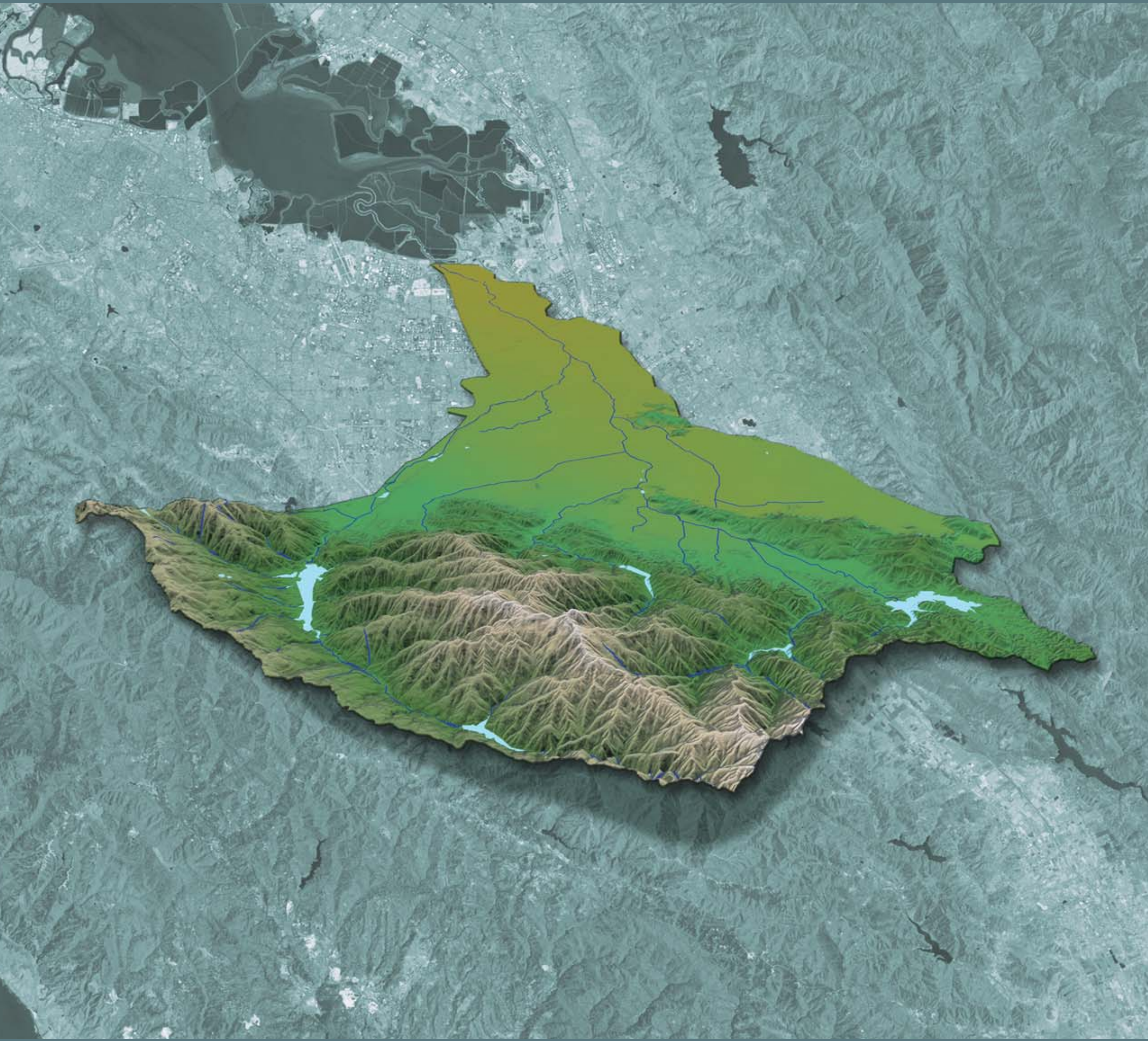
Guadalupe River Watershed Mercury TMDL Project

Final Conceptual Model Report

May 20, 2005



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ACKNOWLEDGEMENTS

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EXECUTIVE SUMMARY

The Watershed: The Guadalupe River Watershed is a large (170 sq. mi.) complex hydrologic system, comprised of six major reservoirs and over 80 miles of streams and rivers. The watershed includes dense forests in its headwaters, at elevations greater than 3,000 feet, and in its mid and lower sections large expanses of housing, and extensive commercial development, the latter supporting services, manufacturing, and the Silicon Valley technology enterprise. At sea level, the Guadalupe River discharges into San Francisco Bay (Figure ES-1).

Mercury Concern: The watershed also contains the New Almaden mercury-mining district, the largest mercury producer in North America. From 1846 to 1975 over 84 million pounds of mercury were produced and shipped, mostly to support the California gold rush. Elemental mercury, a liquid metal at room temperature, was used during the extraction of gold from ore. A comparison of mercury data from water and sediment samples from other gold and mercury mines showed that creeks near mercury mines have higher mercury concentrations than gold mines.

Not all of the mercury left the mining district, however. Most of the mercury remaining in the watershed exists as relatively insoluble mercury sulfides in mine wastes that have accumulated in reservoir deposits and sediments, and in stream bottoms, banks and flood plains. Because of the strong association of mercury with solids, the movement of mercury in the watershed is closely tied to the transport of sediments. The high variability of mercury transport is related to the highly variable flow, sediment load, and transported mercury concentrations measured during the wet season.

Total mercury concentrations in the streams that drain the mining areas were up to 6,667 ng/L in the Mine Hill tributary to Jacques Gulch, which enters Almaden Reservoir (SCPD, 2003). The range of total mercury concentrations measured in the outlets of four reservoirs during the dry season of 2003 was 2.7 – 12.8 ng/L and 7.2 to 49.2 ng/L in the dry season of 2004, compared to 1.4 to 20.0 ng/L in 2003 and 3.5 to 42.8 ng/L in 2004. Methylmercury concentrations in the reservoirs within the mining area are exceptionally high. Maximum methylmercury concentrations in the samples

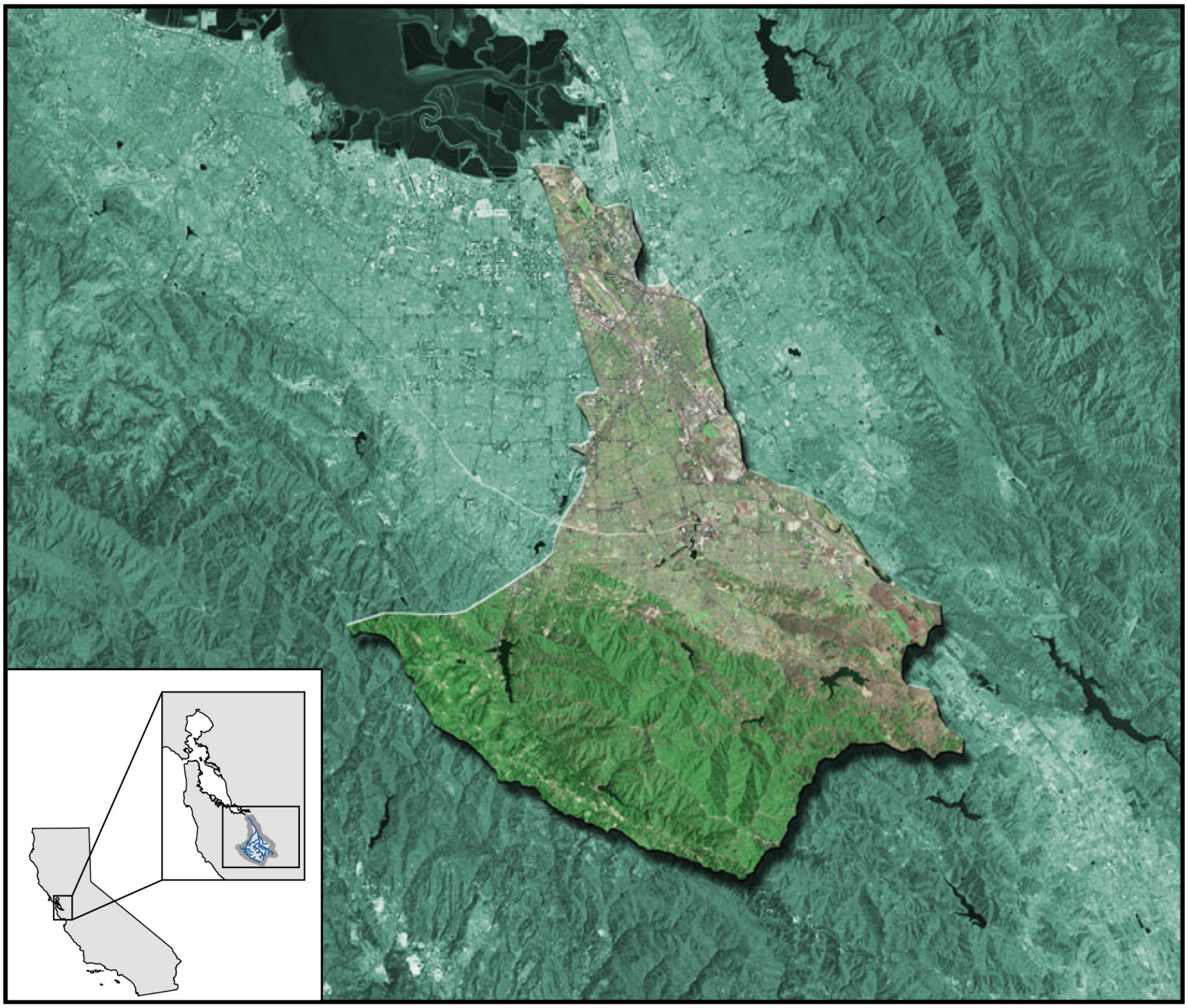

Figure ES-1. Location of Guadalupe River Watershed.

from the reservoir outlets, representing the deeper portion of the hypolimnion, were 7.2 ng/L in Almaden Reservoir and 12.8 ng/L in Guadalupe Reservoir. The problem with mercury, in particular methylmercury, is that it bioconcentrates in the aquatic food chain, producing high mercury concentrations in fish. Fish mercury levels in some of the waterbodies exceed consumption criteria. This has led to fish advisories and postings.

In 1998, in accordance with Section 303 (d) of the Clean Water Act, the California State Water Resources Control Board and the Regional Water Quality Control Board, San Francisco Bay Region listed several waterbodies in the Guadalupe River Watershed as being impaired due to mercury:

- Guadalupe River
- Guadalupe Creek
- Alamitos Creek

- Guadalupe Reservoir
- Calero Reservoir

This impairment listing necessitates the calculation of a Total Maximum Daily Load (TMDL) of mercury for the watershed. The TMDL in essence identifies the maximum amount of mercury that can enter the waterbodies without resulting in the contravention of water quality based standards.

For complex pollutants such as mercury, and in a complex watershed, such as the Guadalupe, the calculation of a TMDL is similarly complex. Formulation of a conceptual model for the system that describes the current understanding of mercury behavior in the watershed can be extremely helpful. In particular the conceptual model describes the processes likely to be controlling mercury transport and fate and identifies additional data needed to address important uncertainties.

The conceptual model is actually a set of statements that describe the current understanding of mercury behavior in the watershed. The uncertainties identified during the conceptual model formulation become the basis for additional field and laboratory investigation. For most other pollutants this is a relatively straightforward process. For mercury, arguably the most complex of all water quality constituents, this requires ongoing efforts of analysis and refinement.

The Conceptual Model: From analyses of the historical data and new results, a conceptual model is emerging for mercury behavior in the Guadalupe River Watershed. The watershed has two distinct hydrologic seasons, a wet winter season and a long dry summer season.

Wet Season: The winter season is punctuated by the advective storms that create large flows in the streams and in the main stem of the Guadalupe River. These large flows are superimposed upon lower flows not that different quantitatively from those of the dry weather season, except that water temperatures are lower. The large storms lead to flows on the main stem that may increase from 10 to over 1000 cubic feet per second (cfs) in less then 24 hours. The high flows recede over 1-2 days. In the upper part of the watershed, the reservoirs typically limit the variability of flow.

The larger rain events, particularly those preceded shortly in time by similar events, create conditions where large quantities of mercury-bearing solids are routed downstream. These solids are believed to originate from hillside drainage, stream sediments, banks, and in some cases flood plains. The larger-sized, mobilized solids in the streams are collected by impoundments created by drop structures and in-stream zones of aggregation. However, during large storms, flows can overtop these drop structures. Above the reservoirs, only suspended sediment is transported downstream, since spilling is extremely rare. Vasona Reservoir, downstream on Los Gatos Creek, spills more often, causing higher suspended solids and mercury to be transported further downstream.

The wet season is largely a season of transport. Methylmercury concentrations are much lower than observed in the outlets of the reservoirs during the warm dry season. But reagents for methylation are being moved into locations where under warmer conditions methylation can occur.

Dry Season: Biogeochemical reactions predominate during the warm dry season. The periodic high flows of winter are past and surface water temperatures increase to values of 65 to 85 ^{o}F. Over the summer, the reservoirs become stratified. Settling of particulate organic matter in summer depletes the lower waters of dissolved oxygen. The reservoirs now are net methlyators of mercury. The methylmercury concentrations in the discharges of Almaden and Guadalupe Reservoirs are high, up to 12.8 ng/l. Methylmercury concentrations in the epilimnetic and upper hypolimnetic waters are less than in the discharge.

Unlike the reservoirs, the creeks in the summer were net demethylators of mercury, with most of the methylmercury in the reservoir releases being lost from the stream water within the first few miles. Although the stream sediment methylmercury concentrations indicate that methylation is occurring at some locations in the creeks, the amount of methylmercury produced is not enough to offset the loss of methylmercury.

Mercury load estimates were made based upon flow and mercury data and modeled flows for selected subwatersheds. Findings from this effort are described below:

1. Most of the total mercury is transported in the wet season, particularly during high flow events.

2. Two major reservoirs, Guadalupe and Calero are sinks for total mercury; they release less total mercury than they receive.

3. Inputs of mercury derived from mine wastes are substantially greater than atmospheric deposition inputs for Guadalupe and Almaden Reservoirs, and for Alamitos and Guadalupe Creeks.

4. The urban creeks contribute less total and methylmercury than the mine-influenced creeks.

5. The total mercury loads from the Guadalupe River have high variability due to varying rainfall from year to year, as seen in the results of a Monte Carlo analysis of loads at the Highway 101 gauging station.

6. While there are multiple uncertainties in the sources of the total and methylmercury load from the Guadalupe River to San Francisco Bay, resuspension of sediments along the main stem of the Guadalupe River and urban storm drains appear to be important contributors.

Mercury Bioaccumulation: The results of the 2004 sampling program established a baseline for fish mercury concentrations in the watershed and have demonstrated the ability to establish a predictive relationship between methylmercury concentrations in water and mercury concentrations in fish tissue. Age-1 largemouth bass (*Micropterus salmoides*) and California roach (*Lavinia symmetricus*) have been shown to be sensitive biosentinels that can be used to monitor recovery in the impoundments and creeks of the watershed. These data from the 2004 sampling program are believed to provide a strong foundation on which to build fish-tissue and aqueous methylmercury numeric targets.

The conceptual model identifies the methylmercury produced in the hypolimnion of impoundments during stratification as an important internal source of methylmercury in the watershed and also a significant entry point of mercury into the food web.

Data Gaps and Uncertainties: The *Final Conceptual Model Report* completes a series of documents developed in Phase 1 of the TMDL for Mercury in the Guadalupe River Watershed. Each document has summarized new information and contributed to the understanding of the biogeochemical processes controlling mercury transport and fate in the watershed. Several data gaps remain and additional data are needed to reduce uncertainties:

- There are large uncertainties in the source of the mercury loads estimated for the Guadalupe River at the Highway 101 gauging station. Additional mercury sampling at high flows of the main tributaries and the main stem of the river are needed to refine the present estimate.

- The predictive relationship between methylmercury concentrations in water and mercury concentrations in fish tissue are based primarily on a single set of samples. The fish data exhibit low variability and are the stronger element of the predictive relationships. An emphasis should be placed on the collection of additional water samples to more fully describe the variability of methylmercury concentrations in the water column.